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HARD X-RAY TELESCOPE (HXT) WITH SIMULTANEOUS MULTIWAVELENGTH OBSERVING FROM UV TO 1 MEV

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The Hard X-Ray Telescope Mission Concept Grant NAG8-1194 Annual Report, Oct. 1, 1997

1 Introduction

The Hard X-Ray Telescope (HXT) mission concept is one of eight missions concepts selected for study from proposals submitted in response to NRA 94 OSS-15, New Mission Concepts in Astrophysics. The study official commenced when funding was provided in October, 1995.

The HXT study is being performed by investigators from the following institutions:

The Smithsonian Astrophysical Observatory
The Marshall Space Flight Center
The Goddard Space Flight Center
The Naval Research Laboratory
The Argonne National Laboratory
The Danish Space Research Institute, (Copenhagen, Denmark)
Centre d'Etude Spatiale des Rayonnements (Tolouse, France)
Brera Observatory (Merate, Italy)

The scientific instrumentation includes three coaligned telescope systems:

- an array of grazing incidence telescopes with graded d-spacing multilayers to enhance reflectivity above 10 keV and a compound detector in their focal planes that covers the 0.1 to 100 keV band,
- a single laue crystal telescope that concentrates selected narrow regions in the 150 to 1300 keV bands containing interesting lines onto a cooled segmented high energy resolution germanium detector,
- an array of three small UV telescopes with detectors and filters to isolate various bands in the 1000 to 2500 A region.

This set of focussing instruments has potentially much more sensitivity for detecting objects and measuring their spectra in the two decades from 10 keV to 1 MeV than non-focussing instruments which are much larger. Indeed, the size of non-focussing hard X-ray instruments may have reached a practical limit with ESA's International Gamma Ray Laboratory (INTEGRAL) due to be launced in 2001. To increase the sensitivity any further will require a different technology such as focussing.

The band, 10 keV to 1 MeV is quite important because it is the regime where active galactic nuclei (AGN) such as quasars emit most of their energy. It is also the regime where the radioactive nuclides formed by a supernova explosion emit gamma rays. These gamma rays consist of discrete lines and are the power source in the early stages following the explosion.

The principal objectives of the study is to define what technology developments are required for these instruments to be built, refine the specifications of each instrument component, and identify what type of mission is needed for an HXT observatory. One key question is whether this set of instruments should be located together as an ensemble observing simultaneously aboard a single dedicated mission or distributed among multiple missions with other instrumentation.

2 Accomplishments

2.1 Introduction

It has been two years since funding was provided. The term of the grant has been extended twice, to two years duration and recently to three years without any increase in funding. The reason for requesting the extensions were much slower than expected delivery on the purchase of equipment built to our design and a greater than anticipated need to identify solutions to problems of technology by carrying out various studies that are funded by other grants. This is described in more detail below.

2.2 The Mission Configuration

2.2.1 Joining Multilayer Telescopes to the HTXS Mission

During the past two years it has become apparent that NASA can support only one new major mission in X-ray astronomy. That mission will almost certainly be the High Throughput X-Ray Spectroscopy (HTXS) mission that was formed from the merger of two other astrophysics mission concepts that were selected for study. HTXS has accumulated the most support from the community. Unless it can be accommodated on the SMEX or MIDEX spacecrafts, which is very unlikely in view of size limitations, there will no separate mission as envisioned by the HXT mission concept: multilayer telescopes, laue crystal telescope, and UV telescopes observing simultaneously on the same platform. Within the framework of current NASA programs there is no provision for an intermediate size astrophysics mission. There are either major missions which occur once per decade and the annual MIDEX launches. HXT cannot compete with HTXS for the former and is too large for the latter. Hence, HXT's scientific objectives are best pursued as much as possible within the HTXS mission and others.

Consequently the decision was made to join HXT to the HTXS mission concept study. HTXS does include hard X-ray grazing incidence telescopes but does not currently specifiy as high an energy limit or as fine angular resolution for them as the HXT study. As part of the HTXS study we will urge the adoption of more ambitious goals in these two respects and propose to carry out technology studies to achieve them as we would have in an HXT technology study. In fact, when technology study funds are offered by NASA we will propose to do the same development tasks in the area of multilayer telescopes that we would have done in a pure HXT mission. Our approach is based upon telescopes made from integral cylindrical substrates with deposition of multilayer coatings upon the interior surfaces. Other groups participating in the HTXS study will propose various approaches based upon segmented cylindrical substrates.

The result of joining the multilayer grazing incidence telescopes of HXT to the HTXS mission changes the constraints upon them. As HTXS consists of six separate moderate size spacecraft rather than the single large spacecraft envisioned for HXT it is necessary to distribute the cluster of hard X-ray telescopes among the six launches. More significantly, the focal length is now limited to 8.5m whereas it was previously 10m. This will likely reduce the upper energy limit to below 100 keV. In addition, the total mass budget for the hard X-ray telescopes is smaller because most of the mass is being allocated to the soft X-ray telescopes. However, the total aperture is somewhat larger summed over the six spacecraft. The limitation is now mass rather than aperture.

The effect of joining the multilayer grazing incidence telescopes of HXT to the HTXS mission is to leave the laue crystal telescope (LCT) without a platform. Although the LCT shares goals of high resolution spectroscopy with HTXS its energy domain is well beyond the X-ray regime and the focal length it requires is too long for the HTXS envelope to accommodate. Since, the LCT science capabilities remain unique for certain science objectives we will continue to examine other possible mission opportunities for it, of ESA as well as of NASA.

2.2.2 Smaller HXT Mission

The role of the 10 to 100 keV multilayer telescopes is more limited aboard HTXS than it would be aboard the original HXT mission. Important objectives are not being addressed by HTXS. This includes the gamma ray emission spectrum of supernova and the abundances of iron, cobalt, and nickel isotopes produced by nucleosynthesis of the explosion. Therefore, a smaller, lower mass HXT mission dedicated to the study of supernova could be made from a reduced number of multilayer telescopes observing and a larger LCT. The multilayer telescopes would only be about one-third as large as before but the LCT would be several times larger in diameter and longer focal length. Since, the LCT has a much lower mass per unit area than the multilayer telescopes there is a reduction in total mass. The question is whether such a reduced mission could be accommodated on a MIDEX platform. The longer focal length of the LCT will require a more elaborate extension system which may not fit within the mass constraints.

2.3 The Multilayer Telescopes

With help from other grants, both NASA and non-NASA, we undertook a project to build prototype integral conical X-ray reflectors with multilayer coatings. The Co-I at the Brera Observatory in Italy, O. Citterio, is making a considerable contribution to the effort. We designed a mandrel for replicating X-ray reflectors and have received bids for its fabrication. Identifying manufacturers was a long and arduous process. However, we are now prepared to issue purchase orders to three companies: (1) Pierce Aluminum of Canton, MA for the mandrel base material, (2) OFC Diamond Turning of Keene, NH for the fabrication, and Capricorn/SSG of Georgetown, MA for the coating and polishing. The fabrication cost exceeds the amount we budgeted "for construction of X-ray reflectors" in the HXT grant. However, we can redirect funds from other activities in the grant to cover this.

The actual replication of the reflectors will be done at the Brera Observatory from our mandrel. The processes will be electroforming and other forms of replication.

We also constructed a facility to coat the interior of cylindrical reflector shells with multilayers. This is a rather elaborate facility and was supported by other grants.

2.4 The Laue Crystal Telescope

The ANL Co-I, R. Smither, with the help of a student from the CESR in Toulouse, France constructed a second generation LCT. This device has an improved means of tuning the crystals. It is based upon a system of micropositioners that are computer controlled. There are plans to test this device upon a French balloon.

3 Publications

Supported in Whole or in Part by Grant NAG8-1194

Density vs Ar-pressures for optimization of DC-magnetron sputter deposition of Ni/C multilayers for hard x-ray telescopes (A.M. Hussain, S.E. Romaine, P. Gorenstein, J. Everett, R.J. Bruni, A.M. Clark, M.F. Ruane, and Y. Fedyunin), SPIE 3113, 260, 1997.

Application of multilayer coatings to replicated substrates (S.E. Romaine, A.M. Hussain, J. Everett, A.M. Clark, R.J. Bruni, P. Gorenstein, M. Ghigo, F. Mazzoleni, O. Citterio, and J. Pedulla), SPIE 3113, 253, 1997.

Hard x-ray telescope mission (P. Gorenstein, D. Worrall, K.D. Joensen, S.E. Romain, M.C. Weisskopf, B.D. Ramsey, J.W. Bilbro, R.A. Kroeger, N.A. Gehrels, A.M. Parson, R.K. Smither, F.E. Christensen, O. Citterio, and P. Von Ballimoos), SPIE. 2807,119, 1996.

Instrumentation of the hard x-ray telescope mission, (P. Gorenstein), SPIE, 2806, 41, 1996.

The hard x-ray telescope mission (P. Gorenstein), in "The Next Generation of X-ray Observatories", M. J. L. Turner and M. G. Watson, Eds. Leicester X-ray Astronomy Group Special Report, 203, 1996.